

Summary Report of the 45th Northeast Regional Stock Assessment Review Committee (SARC 45)

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Executive Summary

The 45th SARC (Stock Assessment Review Committee) met in Woods Hole, Massachusetts, from Monday, June 4, through Friday, June 8, 2007, to review assessments of northern shrimp *Pandalus borealis* and Atlantic sea scallop, *Placopecten magellanicus*.

The review committee was composed of Dr. Michael Prager (NMFS Southeast Fisheries Science Center, chair) and three scientists affiliated with the Center for Independent Experts, University of Miami: Dr. Nick Caputi, Mr. J. J. Maguire, and Dr. Jake Rice. The SARC was assisted by the NEFSC SAW Chairman, Dr. James Weinberg.

The assessment of northern shrimp was presented on behalf of a larger assessment team by Mr. Bob Glenn and Dr. Jason Link, with contributions by Mr. Josef Idoine. Some modest additions and changes were made at the request of the SARC. The most notable were addition of material on model diagnostics and on the stock-recruitment relationship.

The assessment of Atlantic sea scallop was presented for the SAW assessment team by Dr. Dvora Hart and Dr. Larry Jacobson. The changes made at the request of the SARC were not extensive. Most notable was the addition of material on the stock-recruitment relationship.

The SARC concluded that each stock assessment workshop (SAW) had completed its terms of reference successfully. Data were compiled correctly, benchmarks set reasonably, and stock status estimated in accordance with good scientific practice.

The main reservations of the SARC were that biological benchmarks (reference points) for each species were derived without reference to stock-recruitment relationships. While basing benchmarks on recruitment patterns may not always be possible, it should always be attempted. However, the SARC concluded that proposed reference points are acceptable in the short term, but should be re-evaluated at the next assessment and through additional research.

Based on the above, the SARC concurs with the SAW's findings that the stock of northern shrimp is being fished at a rate below its F threshold, and thus, overfishing is not taking place; also, that the stock's biomass is above its biomass threshold, and thus, the stock is not in an overfished state. Likewise, the stock of Atlantic sea scallops is neither undergoing overfishing nor is it in an overfished state.

Major research recommendations of the SARC include work on stock-recruitment relationships in both stocks, including environmental factors if possi-

ble; potential application of a more detailed size-structured model to northern shrimp; and further development of the spatial aspects of modeling and management of Atlantic sea scallop.

1 Introduction

1.1 Background

The 45th SARC (Stock Assessment Review Committee) met in Woods Hole from Monday, June 4, through Friday, June 8, 2007, to review assessments of northern shrimp *Pandalus borealis* and Atlantic sea scallop, *Placopecten magellanicus*.

The members of SARC were the chair, Dr. Michael Prager of the NMFS Southeast Fisheries Science Center; and three scientists affiliated with the Center for Independent Experts, University of Miami: Dr. Nick Caputi, Mr. J. J. Maguire, and Dr. Jake Rice. The SARC was aided by the NEFSC SAW chairman, Dr. James Weinberg, and by staff of the NMFS Northeast Fisheries Science Center (NEFSC), Massachusetts Division of Marine Fisheries, and Atlantic States Marine Fisheries Commission.

About two weeks before the meeting, assessment documents and supporting materials were made available to the SARC via a Web page. Shortly thereafter, the assessment teams, at the request of the committee, made basic data used in the assessments available as Excel spreadsheets for review and exploration. Additional documents were added as available. During the meeting, all documents were available electronically and in print.

In the weeks preceding the meeting, the chair convened two brief conference calls with J. Weinberg and analysts representing the assessment teams. Analysts were briefed on the scope and length of presentations expected and the general scope and aims of the meeting, as reflected in the Statement of Work supplied to the review committee.

Leadership duties during the SARC were divided among the committee members. J. Rice led review of the northern shrimp assessment; N. Caputi and J. J. Maguire led review of the Atlantic sea scallop assessment, with Caputi emphasizing review of data and Maguire emphasizing review of models; and M. Prager served as overall chair of the meeting.

1.2 Review of Activities

The first day of the meeting (Monday) was devoted to reviewing the northern shrimp assessment. The assessment was presented on behalf of a larger assessment team by Mr. Bob Glenn of the Massachusetts Division of Marine Fisheries and Dr. Jason Link of the NEFSC, with contributions by Mr. Josef Idoine of the NEFSC. During the presentation, the SARC asked for additional detail on some work of the Stock Assessment Workshop (SAW) discussed during the

presentation but not fully described in the assessment report. The review committee also requested that a stock-recruitment plot and corresponding narrative be prepared. The additional material, once reviewed by the SARC, was to be added to the assessment report.

During the second day of the meeting (Tuesday), the SARC reviewed the assessment of Atlantic sea scallop. This was presented on behalf of the assessment team by Dr. Dvora Hart, with the collaboration of Dr. Larry Jacobson, both of the NEFSC. The SARC asked the presenters to prepare a few additions to the assessment report after review. These additions were intended to describe in more detail some of the work done by the assessment team during the SAW. The SARC also requested that a stock-recruitment plot and text describing work on stock and recruitment relationships be prepared for addition to the assessment report.

On Wednesday morning, B. Glenn, J. Link, and J. Idoine, representing the northern shrimp assessment team, put forward work done to answer the SARC's requests. After reviewing that material, the SARC engaged in a detailed review of the Assessment Summary document on northern shrimp. Numerous revisions and clarifications were proposed—both by members of the review committee and by local participants—with the aim of presenting the assessment as clearly and accurately as possible to a wide group of readers.

On Wednesday afternoon, D. Hart, representing the Atlantic sea scallop assessment team, presented work answering the SARC's requests. Dr. Anne Richards (NEFSC) then summarized her work with colleagues on the stock-recruitment relationship in northern shrimp, including environmental factors affecting recruitment. After reviewing that material, the SARC conducted its review of the Assessment Summary on Atlantic sea scallop. Again, suggestions and clarifications were proposed to present the assessment as clearly and accurately as possible to its expected wide readership.

On Thursday and Friday, the SARC continued drafting its reports. The SARC adjourned on Friday evening after agreeing to correspond by email until completion of all required reports.

2 Review of northern shrimp assessment

2.1 Terms of reference

The SARC considered the northern shrimp assessment in light of the terms of reference (TOR) provided to the SAW, as follows:

1. Characterize the Gulf of Maine northern shrimp commercial catch, ef-

fort, and CPUE, including descriptions of landings and discards of that species.

2. Estimate fishing mortality and exploitable stock biomass in 2006 and characterize the uncertainty of those estimates. Also include estimates for earlier years.
3. Comment on the scientific adequacy of existing biological reference points (BRPs).
4. Evaluate current stock status with respect to the existing BRPs.
5. Perform sensitivity analyses to determine the impact of uncertainty in the data on the assessment results.
6. Analyze food habits data and existing estimates of finfish stock biomass to estimate annual biomass of northern shrimp consumed by cod and other major predators. Compare consumption estimates with removals implied by currently assumed measures of natural mortality for shrimp.
7. Review, evaluate and report on the status of the 2002 SARC/Working Group Research Recommendations.

2.2 SARC findings by term of reference

2.2.1 Data compilation and characterization

The SARC concluded that data on northern shrimp were compiled and characterized well. Therefore, this TOR was completed successfully.

The SARC suggested modest changes to the assessment report to more completely, accurately, or precisely describe various topics. Those suggestions were accepted by the assessment team and thus should be reflected in the final assessment report.

- Discarding was characterized as “trivial” in the draft assessment report. However, it appears that discards of shrimp in shrimp and finfish fisheries are not well quantified and have probably been substantial at times. Thus the extent of discarding would be better characterized as “unknown.”
- At the SARC’s request, AR Table C3¹ was supplemented to include information on number of length samples per metric ton (mt) of catch. The

¹References to tables and figures in the assessment reports, as here, are prefixed with “AR.”

SARC concluded that the sampling intensity for length composition generally has been acceptable, but in a few years and areas, the sampling fraction was not large enough to represent the catch with acceptable precision. Increased sampling would lead to greater precision in estimates of length composition, and thus greater precision in assessment results.

- In 2006, the fall trawl survey index reached its highest value in about 30 years. Because survey indices of abundance typically have high variance, there is concern about accepting a single extreme value as definitive. However, evidence of high abundance was also seen in commercial catch rates (AR Fig. A.5.8) and the NSTC summer index (AR Fig. A.6.5). To investigate further, the SARC examined plots of spatial distributions of catches from recent surveys. The spatial allocation of sets and pattern of abundances in recent high-abundance years do not appear anomalous, but because the number of successful survey sets was the lowest to date, the 2006 estimate has a large confidence interval.

The SARC noted that abundance of all sizes of shrimp from 2004 to 2005 and from 2005 to 2006 increased together, suggesting that high abundance estimates in 2006 were accompanied by increased availability to the survey gear. If catchability was anomalously high in the 2005 and 2006 surveys, the resulting survey-index values would lead the assessment model to overestimate abundance. In summary, although 2006 abundance is undoubtedly high, it may not be as high as indicated by the survey and CSA.

2.2.2 Estimates of fishing mortality rate and biomass

The SARC concluded that the assessment team met this term of reference successfully. The SARC commends the use of more than one model in any assessment. The committee also agrees that here the Collie-Sissenwine analysis (CSA) is more appropriate than the production model (ASPIC), because ASPIC is not well suited to modeling stocks driven by recruitment events unrelated to population size. This is of particular relevance in this assessment, in which apparent yearclass strength varies markedly.

Nonetheless, the application of ASPIC is useful, as it is a well-tested assessment model that imposes more structure on population dynamics than CSA—although that structure prevents modeling rapid population changes. In summary, neither model is perfect, and results of each should be examined in light of its strengths and limitations. The large measure of agreement between the models reinforces the credibility of assessment results.

These further considerations on estimates of F and B were noted:

- As is commonly the case, terminal-year estimates (AR Fig. A.6.8) have more uncertainty than those in preceding years. This terminal-year effect is amplified by the very high 2006 survey values with correspondingly large uncertainties. There is nonetheless strong evidence that fishing pressure is low (partly because of low prices) and that the stock was abundant in 2006.
- The finding that retrospective pattern in the analysis are relatively small (AR Fig. A.6.13 and following) increases confidence in estimates of recent stock status and exploitation.
- The assessment team presented several lines of evidence that the assumed $M = 0.25/\text{yr}$ is probably too low and that $M = 0.6/\text{yr}$ is more likely in the right range. Through sensitivity analyses, it was shown that estimates of stock status and biomass trends are relatively robust to this assumption.
- Diagnostic plots generated at the request of the SARC displayed reasonably good fits of the CSA model to the data. Fit was better under the assumption $M = 0.6/\text{yr}$ than under $M = 0.25/\text{yr}$.
- There is an apparent influence of water temperature (or factors correlated with it) on recruitment in this stock. If so, a production model modified to include environmental influences would be expected to track the stock's dynamics better than the standard production model used now.
- In some periods, such as December, March and April, many small shrimp are caught. Because the market prefers larger shrimp, exploration of ways to increase the mean size of shrimp and reduce discards should be considered. These might include analysis of spatial distribution of size and abundance by month and analysis of mesh sizes to ensure that a more desirable size composition is retained.
- It might be possible in the future to fit a more detailed assessment model, such as the recently elaborated CASA model of catch at size used for Atlantic sea scallop. That would be a desirable improvement that could reduce uncertainty in assessment results.

2.2.3 Adequacy of reference points

The SARC concluded that, after the addition of material on stock and recruitment requested at the meeting, this term of reference was met satisfactorily.

The current biological reference points apparently are heuristic and not based on considerations of stock productivity, which would be preferable. To base new reference points on stock productivity, further study of the dependence of recruitment on stock size will be necessary, ideally including influence of environmental factors on recruitment and spawning success (recruits per spawner).

The stock has been shown vulnerable to overfishing by its collapse during the 1970s due to increasing fishing pressure. Being at the southern extent of its range, the stock is more vulnerable to environmental influences, particularly trends such as steady temperatures increases associated with global climate change.

Despite preference for reference points that take productivity into account, the SARC concluded that, given current low market demand for northern shrimp and current high stock size, there is minimal risk to productivity from using the current reference points in the immediate future. Nonetheless, if the assumption on M is changed, reference points will require recomputation.

A research summary, given as part of the assessment report by J. Link, estimated consumption of northern shrimp by cod and other major predators. Further refinement of those estimates could contribute to improving reference points for and assessments of northern shrimp. (See also §2.2.6.)

Another summary of continuing research by A. Richards (NEFSC) and colleagues was presented by Dr. Richards. This research into possible environmental influences on recruitment seems promising and may eventually allow development of new reference points more firmly grounded in considerations of stock productivity. That would be preferable to continued use of heuristic reference points.

It is essential that research continue to investigate factors affecting stock productivity and that reference points be revised as necessary in future assessments.

2.2.4 Status relative to reference points

The SARC concluded that the assessment team met this term of reference successfully. Both the primary assessment model (CSA) and the confirmatory model (ASPIC) estimate that current fishing mortality is below the F threshold. Both models also estimate that stock abundance is high.

Because reference points were developed under the assumption $M = 0.25/\text{yr}$, it was necessary to compare them to stock estimates under the same assumption, as was done by the assessment team.

2.2.5 Impacts of data uncertainty

The SARC concluded that the assessment team met this term of reference successfully. In particular, analyses were performed on sensitivity to mean weight, underreported landings, and value of natural mortality M .

Sensitivity to model uncertainty was examined by using two assessment models. The research recommendations of the SARC (§2.3.2) include suggestions for additional sensitivity analysis in future assessments.

2.2.6 Consumption estimates

The SARC concluded that the assessment team met this term of reference successfully. Estimates presented by J. Link suggested that shrimp consumption by predators is substantial, considerably larger than fishery catches in some years. Although estimating consumption required numerous assumptions, they were considered plausible, and work is underway to test key assumptions. Because predation is a major component of natural mortality, the research supports a rate of natural mortality higher than $M = 0.25/\text{yr}$, the current assumption, and implies that M may vary from year to year.

2.2.7 Review 2002 research recommendations

Not every recommendation made in 2002 has been carried to fruition by researchers in the interval. Nonetheless, progress has been made on several of the most important recommendations, including better understanding of the rates of natural mortality M and total mortality Z . The SARC concluded that the assessment team completed this term of reference successfully.

2.3 SARC research recommendations on northern shrimp

2.3.1 Data collection

1. Data collection on discard rates in the northern shrimp fishery would be useful, not just with respect to shrimp, but to quantify discards of finfish. It is also recommended to sample shrimp discards in the small-mesh herring and whiting fisheries.

2. Increased sampling of commercial catches, ensuring good allocation of samples among ports and months, could provide better estimates of size composition.
3. Research on annual variation of size at age could increase precision of the assessment.

2.3.2 Modeling

1. The possibility of using a more detailed assessment model, such as the CASA model used for Atlantic sea scallop, should be studied. Use of a model with a more detailed treatment of northern shrimp population dynamics could increase accuracy and precision of assessment results.
2. The relevance of environmental effects should be investigated in several contexts—
 - (a) Survey index—Exploration of any spatial, depth, or temperature influences on survey catchability could contribute to better standardization of the survey abundance index.
 - (b) Stock and recruitment—It appears that temperature-correlated effects contribute to variation in the stock-recruitment relationship. Such effects should be examined further through continuing the type of research presented by A. Richards.
 - (c) Surplus production—Environmental effects could likewise be examined through development of a surplus-production model that includes effects of environmental variation on per-capita production or carrying capacity.
3. The CSA model as used here requires a parameter that is the ratio of catchabilities for the two age or size classes. Sensitivity analysis on the values used would contribute to a better understanding of model stability. A thorough evaluation of possible methods for better estimating this parameter could reduce uncertainty in the assessment.
4. Further research to refine annual estimates of consumption by predators could be useful in several ways. Consumption estimates could lead to annual estimates of M that would be more realistic than assuming constant M , for use in models that include M explicitly. Alternatively, consumption estimates could be used in production models as annual removals similar to fishery removals.

5. It seems likely that M will be assumed constant over time until annual consumption estimates can be refined and methods developed to provide them on an annual basis. In that case, the best value of M appears to be substantially higher than 0.25/yr. Unless new evidence appears to the contrary, a suitable higher value should be identified and used in future assessments. Such a change in the value used for M will require reference points to be recomputed.
6. Target and threshold reference points for northern shrimp are set equal to one another at $F = 0.22/\text{yr}$. Using a buffer of zero between target and threshold reduces the relevance of reference points to management. Specifically, the distinction between desirable exploitation rates and those that indicate overfishing is blurred. The SARC recommends dialogue with managers and industry on this matter, as well as research to illustrate whether separating threshold from target would allow more stable or robust management techniques. When a common agreement exists about the function of each reference point, assessment scientists can calculate values to best serve each function.

3 Review of Atlantic sea scallop assessment

3.1 Terms of reference

The SARC considered the assessment in light of the terms of reference (TOR) provided to the Atlantic sea scallop SAW, as follows:

1. Characterize the commercial catch, effort and CPUE, including descriptions of landings and discards of that species.
2. Estimate fishing mortality, spawning stock biomass, and total stock biomass for the current year and characterize the uncertainty of those estimates. If possible, also include estimates for earlier years.
3. Either update or redefine biological reference points (BRPs; proxies for B_{MSY} and F_{MSY}), as appropriate. Comment on the scientific adequacy of existing and redefined BRPs.
4. Evaluate current stock status with respect to the existing BRPs, as well as with respect to updated or redefined BRPs (from TOR 3).
5. Recommend modeling approaches and data to use for conducting single- and multi-year stock projections, and for computing TACs or TALs.
6. If possible,
 - a. provide numerical examples of short term projections (2–3 years) of biomass and fishing mortality rate, and characterize their uncertainty, under various TAC/ F strategies and
 - b. compare projected stock status to existing rebuilding or recovery schedules, as appropriate.
7. Review, evaluate and report on the status of the SARC/Working Group research recommendations offered in recent SARC reviewed assessments.

3.2 SARC findings by term of reference

3.2.1 Data compilation and characterization

The SARC concluded that the assessment team met this term of reference successfully. Data on catch, effort, and landings per effort were successfully compiled and interpreted, along with basic biological data. Much has been accomplished since the last assessment to improve data collection and interpretation. In particular, new growth modeling and verification, revision of the

shell height–meat weight relationship, adjustments for shucking capacity, and re-estimation of selectivity in scallop dredges have contributed to better data treatment.

The scallop fishery has had very good observer coverage, much of it funded by the industry, since about 2003. This provides valuable information on operations. Data from vessel monitoring systems also contribute to improving the assessment.

3.2.2 Estimates of fishing mortality rate and biomass

The SARC concluded that the assessment team met this term of reference successfully. Considerable progress was described in improving and testing CASA, the primary assessment model. CASA is a size-structured model that can treat directly the type of length information available (growth-increment probabilities). This match of model and data seems likely to contribute to better precision and reduced model-specification bias, compared to typical methods that require direct estimates of size at age.

The SARC supports the SAW’s approach of modeling the Mid-Atlantic and Georges Bank areas separately before combining assessment results. This is appropriate for several reasons, among them the difference observed in recruitment patterns between the two areas.

The cancelation of retrospective patterns when CASA results are combined across the two areas is fortunate. However, cancelation does not indicate that retrospective patterns in the two areas have similar causes, nor does it imply that cancelation must occur in future assessments. Retrospective patterns in CASA results for the individual areas are considerably larger. It is possible—but not certain—that continued model development and better knowledge of biology or fishing practices might reduce retrospective patterns in CASA area-specific estimates.

A representative range of sensitivity analyses and likelihood profile analyses on the assessment results was conducted by the SAW.

3.2.3 Update or redefine reference points

The SARC concluded that, with the addition of information on stock and recruitment requested during the SARC meeting, this term of reference was met satisfactorily. Several topics on reference points were discussed:

- The assessment team appropriately recomputed reference points to reflect new information on growth and selectivity. The SARC agrees with

the assessment team that reference points should always be computed under the same assumptions used to estimate population status. Thus, we concur with the recommendation to use the updated reference points proposed in the assessment report.

- Existing and proposed biological reference points are based on yield per recruit, rather than on considerations of stock productivity (stock and recruitment), which also should be taken into account. Nonetheless, the yield-per-recruit benchmarks in F seem of reasonable magnitude compared to other mortality components. Recent changes in selection towards larger scallops, through changes in gear and area-based management, appear to have helped increase spawning stock and, together with the use of closed areas, may provide some protection against recruitment overfishing, thus lessening—but not removing—concern about the use of reference points based only on yield per recruit.
- The practice of setting a B reference point by reference to F_{\max} , although consistent with use of F_{\max} as a proxy for F_{MSY} , does not have a firm theoretical basis. This is for three quite different reasons: (1) the method depends on an assumed recruitment; (2) it does not consider the marked spatial character of this fishery; and (3) the conceptual basis of using reference points is preservation of the productive capacity of the resource. Thus the benchmark fishing mortality rate should be chosen to ensure sufficient biomass to protect stock productivity, but this property is not part of the computation of F_{\max} .
- The SARC asked the assessment team to prepare a description of the SAW's work on stock and recruitment relationships for inclusion in the assessment report. As part of their response, the assessment team generated scatterplots of egg production versus recruits in each of the two areas.

The stock-recruitment data are only marginally informative in judging appropriateness of the proposed reference points. The proposed target biomass of 109,000 mt for the combined areas corresponds to 120×10^{15} eggs (given the current size structure of the scallop stock), divided equally between Georges Bank and the Mid-Atlantic (60×10^{15} eggs in each area). Recruitment in each area seems unimpaired as long as area-specific egg production is above about 15×10^{15} to 20×10^{15} eggs, considerably lower than the target biomass equivalent. However, because relatively few observations are available at high egg production, it is im-

possible to reach firm conclusions on the appropriateness of the proposed biomass reference points.

3.2.4 Status relative to reference points

The SARC concluded that the assessment team completed this term of reference successfully. The questions concerning reference points, described in §3.2.3, reflect on stock status relative to those reference points.

3.2.5 Recommend models and data for projections, TACs

The SARC concluded that the assessment team met this term of reference successfully. In particular, the SARC supports use of the SAMS model for projections. SAMS is more realistic than most models used for such projections, as it includes spatial considerations, both by modeling Georges Bank and the Mid-Atlantic separately and by simulating the rotational and long-term closures used in management. The model includes separate mortality factors for capture, discard, incidental, and natural mortalities, a level of detail not possible in most projection models.

The biggest question in the existing projection methodology is generation of recruitment as unrelated to spawning stock and instead drawn as independent observations from a statistical distribution. The actual recruitment estimates presented during the SARC appeared to exhibit autocorrelation from year to year. When autocorrelation exists, it can be used to more realistically model recruitment in stock projections, a refinement that would improve forecasts, particularly short-term forecasts.

3.2.6 Examples of short-term projections

The SARC concluded that the assessment team met this term of reference successfully. Comments in §3.2.5 apply equally to the sample projections provided. Projection methodology incorporating information from the observed recruitment patterns, e.g., autocorrelation patterns or stock-recruitment relationships, if they can be better defined, should improve the accuracy of future projections—although all stock projections are inherently uncertain.

At the request of the SARC, the assessment team added to the mean projections and their confidence intervals (AR Fig. B8-1) some of the individual projection trajectories. The revised figures should illustrate better the variability estimated in the projection period and the typical scale of year-to-year fluctuations likely to be observed in the stock.

The SARC noted that using a wider range of fishing mortality rates (including the target F) in future projections would be more informative.

3.2.7 Review recent research recommendations

The SARC concluded that the assessment team met this term of reference successfully. It was notable that each research recommendation either had been completed, was the subject of work in progress, or was planned for further research.

3.3 SARC research recommendations on Atlantic sea scallop

3.3.1 Recommendations in the assessment document

The assessment report includes a section of research recommendations, which all seem useful topics to improve assessment of Atlantic sea scallop. The SARC supports particularly strongly those recommendations that involve strengthening basic data collection and analysis, as well as those that incorporate the spatial characteristics of the resource, fishery, and management more accurately into the assessment and projection methodology.

3.3.2 Data collection

1. Further research on scallop growth could improve the accuracy of assessments. It would be helpful to understand whether growth varies over time or by area, and if so, how. In exploring these questions, it would probably be useful to re-evaluate the historical archives of scallop shells for growth analysis.
2. Also deserving more study are discard mortality rates of scallop. This seems particularly necessary in the Mid-Atlantic, where higher temperatures on deck—which have been demonstrated to increase mortalities—are found.
3. The dredge survey has provided an abundance index that is unusually precise (through coverage of about 500 tows/yr recently), and that has helped make possible a relatively precise assessment. The assessment team expressed uncertainty about the future of the dredge survey. The SARC emphasizes the need to maintain some kind of comprehensive survey of this stock. A comprehensive survey is needed for stock assessment to be continued with confidence.

3.3.3 Modeling

1. Further in-depth research on the stock–recruitment relationship is important, including possible environmental influences and oceanographic links between regions.
2. Setting biomass reference points in terms of egg production, rather than spawning stock biomass, should be considered. According to the assessment team, egg production is nonlinearly related to shell height, and thus nonlinearly related to spawning biomass.
3. The assessment report notes that, under spatial variability in fishing mortality, the actual F_{\max} is probably less than the rate estimated by methods not modeling the spatial variability. However, the report does not give an estimate of the bias. The SARC recommends research to estimate this bias and, more broadly, research into methods for estimating benchmarks when F varies spatially and some portions of the stock are only periodically available. This might be research on assessment and simulation models that consider open and closed areas separately.
4. Parallel research should be conducted to expand the range and efficiency of management techniques available for stocks managed using spatial measures and those with strong spatial structure.
5. Projections should use autocorrelated recruitment if that is characteristic of the stock, as it seems to be here.
6. Per recruit analyses could be improved in several ways—
 - (a) Most importantly, analyses of yield per recruit should use both fishing mortality rate and selectivity (size at capture) as control variables, not only fishing mortality rate.
 - (b) Analyses of spawning per recruit—based on egg production, as this is believed to be nonlinearly related to individual weight—would add to knowledge of reproductive biology and provide more insight into management options.
 - (c) An analysis of economic value achieved per recruit would be simple to conduct and should be useful to managers, particularly in evaluating economic consequences of size selection in the fishery.
 - (d) In some stocks, F_{\max} can be difficult to estimate, as here (AR Fig. B6-1, center right panel). If reference points based on per-recruit

calculations continue to be used, a reference point similar in concept to $F_{0.1}$ (e.g., $F_{0.05}$) might be more stably estimated.

7. Future assessment reports and summaries should describe target reference points, not only threshold and limit reference points.²

4 SARC general comments

4.1 Research and reporting recommendations

This section contains research and operational recommendations that apply equally to both species under review.

1. The SARC recommends that a thorough exploration of the stock-recruitment relationship be part of all assessment documents. This is a fundamental part of a stock's biology, is helpful when deciding on projection methodology, and is a preferred first line of attack when setting reference points. Moving beyond basic stock-recruitment models to those incorporating environmental factors should be attempted when possible.

Even when the overall stock-recruitment relationship appears weak, one might find other patterns; e.g., that at low spawning biomass the likelihood of low recruitment increases markedly. Such information is important in developing general management advice and aids in establishing biologically appropriate reference points.

2. The SARC recommends that, when projections are made, careful consideration be given to the most realistic way to simulate recruitment, a decision that typically has a strong influence on the estimated trajectories. For short-term projections, it seems important to examine recruitment series for autocorrelation, and to include it in the projection methodology when found.

When a strong environmental influence on recruitment is documented, projections should not assume that average environmental conditions will prevail. Analysis of data on climate, perhaps in collaboration with oceanographers or climatologists, should be used to establish appropriate environmental scenarios for projections.

²Information was provided to the review committee by D. Hart following the meeting. The current fishing mortality target is $F = 0.20/\text{yr}$, and the corresponding threshold is $0.24/\text{yr}$. The 2006 fishing mortality was thus below the F threshold, but above the F target.

3. The SARC recommends that assessment authors be encouraged to include research recommendations in all assessment reports. Each recommendation is best accompanied by a statement of the resources needed to achieve it and the expected benefits from its achievement.
4. The SARC recommends that input files and output files from base runs of assessment models be included in the assessment report as appendices. This would provide a more solid audit chain of the data and settings used in those runs. We further recommend that the same information be supplied to reviewers in computer-readable form.
5. The SARC recommends that when assessment or projection models are programmed specifically for a stock (as in the Atlantic sea scallop assessment), the models' computer code be added to the assessment report as an appendix. That would provide a more complete record of the assessment.

4.2 SARC process recommendation

During the detailed review of Stock Assessment Summaries, local participants put forward numerous additions to or other modification of the documents to reflect customary practices. While this procedure improved the summary documents, it was surprisingly lengthy. That our review of these summaries was prolonged, even though the drafts supplied were well written, suggests the need for additional guidance to the authors. The SARC recommends that written guidelines, perhaps supported by a detailed template, be developed to guide staff in drafting summary documents to meet local expectations. Subsequent review by a copy editor could produce a document consonant with local practices and ready for review by the SARC.

4.3 Execution of SAW/SARC process

The SARC received a clear statement of work from the NEFSC, which greatly simplified the completion of its work. Facilities provided by the NEFSC were well suited to completion of SARC duties. Documents were supplied in a timely fashion, and requests by the review committee for detailed data files before the meeting were accommodated promptly. Presentations by representatives of the assessment teams were well prepared and comprehensive.

The members of this SARC believe that the SAW/SARC process is well structured for conducting and reviewing stock assessments. In particular, the workshop structure of the SAW brings a wider range of expertise into the assess-

ment process than use of a single author. Including standing research recommendations in the SAW Terms of Reference ensures that those recommendations are not overlooked. The limited authority given the SARC—to approve or disprove work but not reshape it—is appropriate for outside reviewers constrained by time. That limitation ensures that accountability for assessments remains with local investigators, who are most knowledgeable of local conditions. By keeping authorship and review distinct, the SAW/SARC structure preserves integrity of the review process.

In summary, the review committee concludes that the SAW/SARC process adds significant value to the assessment cycle, both by expanding the number of viewpoints and areas of expertise and by ensuring a higher degree of completeness and correctness.

5 Acknowledgements

The SARC could not have completed its assignment without the dedication and hard work of the participating assessment scientists, who were true collaborators. The SARC rapporteurs, Brad Spear and Toni Chute, by their diligence simplified the preparation of this report considerably. The review committee also thanks Dr. James Weinberg for his organization and help before, during and after the SARC meeting.

References

- Anon. 2007. Northern shrimp assessment summary for 2007. Report dated as revised 5/24/07. 13 p.
- Glenn, R., M. Hunter, J. Idoine, C. McBane, B. Spear, and J. Link. 2007. Assessment report for Gulf of Maine northern shrimp. Report dated May 16, 2007. 66 p. + Figures.
- Invertebrate Subcommittee. 2007a. Stock assessment summary for Atlantic sea scallops (*Placopecten magellanicus*). Report dated May 17, 2007. 11 p.
- Invertebrate Subcommittee. 2007b. Stock assessment for Atlantic sea scallops (*Placopecten magellanicus*). Report dated May 16, 2007. 69 p. + 63 p. of figures.

Appendix A Statement of Work

SARC 45: Statement of Work for CIE Reviewers (including a description of SARC Chairman's duties)

(DRAFTED: 3-15-07)

General

The Northeast Regional Stock Assessment Review Committee (SARC) meeting is a formal, multiple-day meeting of stock assessment experts who serve as a panel to peer-review tabled stock assessments and models. The SARC is the cornerstone of the Northeast Stock Assessment Workshop (SAW) process, which includes assessment development (SAW Working Groups or ASMFC technical committees), assessment peer review, public presentations, and document publication.

The SARC45 review panel will be composed of three appointed reviewers from the Center of Independent Experts (CIE), and a chair from the Scientific and Statistical Committee (SSC) of the regional Fishery Management Councils. The panel will convene at the Woods Hole Laboratory of the Northeast Fisheries Science Center (NEFSC) in Woods Hole, Massachusetts, from June 4-9, 2007 to review two assessments (Atlantic sea scallop, *Placopecten magellanicus*; Northern shrimp, *Pandalus borealis*). In the days following the review of the assessments, the panel will write the SARC Summary Report and each CIE reviewer will write an individual independent review report.

Specific Activities and Responsibilities

The CIE's deliverables shall be provided according to the schedule of milestones listed on Page 5. The CIE reviewers, along with input from the SARC Chairman, will write the SARC Summary Report. In addition, each CIE reviewer will write an individual independent review report. These reports will provide peer-review information for a presentation to be made by NOAA Fisheries at meetings of the New England and Mid-Atlantic Fishery Management Councils in 2007. The SARC Summary Report shall be an accurate and fair representation of the SARC panel viewpoint on how well each SAW Term of Reference was completed (please refer to Annex 1 for the SAW Terms of Reference).

The three SARC CIE reviewers' duties shall occupy a maximum of 14 days per person (i.e., several days prior to the meeting for document review; the SARC meeting in Woods Hole; and several days following the open meeting to contribute to the SARC Summary Report and to produce the Independent CIE Reports).

The SARC chair's duties shall occupy a maximum of 17 days (i.e., several days prior to the meeting for document review; the SARC meeting in Woods Hole; several days following the open meeting for SARC Summary Report preparation.)

Charge to SARC panel

The panel is to determine and write down whether each Term of Reference of the SAW (see Annex 1) was or was not completed successfully during the SARC meeting. To make this determination, panelists should consider whether the work provides a scientifically credible basis for developing fishery management advice. Criteria to consider include: whether the data were adequate and used properly, the analyses and models were carried out correctly, and the conclusions are correct/reasonable. Where possible, the chair shall identify or facilitate agreement among the reviewers for each Term of Reference of the SAW.

If the panel rejects any of the current Biological Reference Point (BRP) proxies for B_{MSY} and F_{MSY} , the panel should explain why those particular proxies are not suitable and the panel should recommend suitable alternatives. If such alternatives cannot be identified, then the panel should indicate that the existing BRPs are the best available at this time.

Roles and responsibilities

(1) Prior to the meeting

(SARC chair and CIE reviewers)

Review the reports produced by the Working Groups and read background reports.

(2) During the Open meeting

(SARC chair)

Act as chairperson, where duties include control of the meeting, coordination of presentations and discussion, making sure all Terms of Reference of the SAW are reviewed, control of document flow, and facilitation of discussion. For each assessment, review both the Assessment Report and the Assessment Summary Report.

During the question and answer periods, provide appropriate feedback to the assessment scientists on the sufficiency of their analyses. It is permissible to discuss the stock assessment and to request additional information if it is needed to clarify or correct an existing analysis and if the information can be produced rather quickly.

(SARC CIE reviewers)

For each stock assessment, participate as a peer reviewer in panel discussions on assessment validity, results, recommendations, and conclusions. From a

reviewer's point of view, determine whether each Term of Reference of the SAW was completed successfully. Terms of Reference that are completed successfully are likely to serve as a basis for providing scientific advice to management. If a reviewer considers any existing Biological Reference Point proxy to be inappropriate, the reviewer should try to recommend an alternative, should one exist.

During the question and answer periods, provide appropriate feedback to the assessment scientists on the sufficiency of their analyses. It is permissible to request additional information if it is needed to clarify or correct an existing analysis and if the information can be produced rather quickly.

(3) After the Open meeting

(SARC CIE reviewers)

Each reviewer shall prepare an Independent CIE Report (see Annex 2). This report should explain whether each Term of Reference of the SAW was or was not completed successfully during the SARC meeting, using the criteria specified above in the "Charge to SARC panel" statement.

If any existing Biological Reference Point (BRP) proxies are considered inappropriate, the Independent CIE Report should include recommendations and justification for suitable alternatives. If such alternatives cannot be identified, then the report should indicate that the existing BRPs are the best available at this time.

During the meeting, additional questions that were not in the Terms of Reference but that are directly related to the assessments may be raised. Comments on these questions should be included in a separate section at the end of the Independent CIE Report produced by each reviewer.

If a reviewer feels that his/her comments are adequately expressed in the SARC Summary Report, it will not be necessary to repeat the same comments in the Independent CIE Report. In that case, the Independent CIE Report can be used to provide greater detail on specific Terms of Reference or additional questions raised during the meeting.

(SARC chair)

The SARC chair shall prepare a document summarizing the background of the work to be conducted as part of the SARC process and summarizing whether the process was adequate to complete the Terms of Reference of the SAW. If appropriate, the chair will include suggestions on how to improve the process. This document will constitute the introduction to the SARC Summary Report.

(SARC chair and CIE reviewers)

The SARC Chair and CIE reviewers will prepare the SARC Summary Report. Each CIE reviewer and the chair will discuss whether they hold similar views on each Term of Reference and whether their opinions can be summarized into a single conclusion for all or only for some of the Terms of Reference of the SAW. For terms where a similar or a consensual view can be reached, the SARC Summary Report will contain a summary of such opinions. In cases where multiple and/or differing views exist on a given Term of Reference, the SARC Summary Report will note that there is no agreement and will specify - in a summary manner – what the different opinions are and the reason(s) for the difference in opinions.

The chair's objective during this Summary Report development process will be to identify or facilitate the finding of an agreement rather than forcing the panel to reach an agreement if it cannot reach one. The chair will take the lead in editing and completing this report. The chair may express the chair's opinion on each Term of Reference of the SAW, either as part of the group opinion, or as a separate minority opinion.

The SARC Summary Report (please see Annex 3 for information on contents) should address whether each Term of Reference of the SAW was completed successfully. For each Term of Reference, this report should state why that Term of Reference was or was not completed successfully.

If any existing Biological Reference Point (BRP) proxies are considered inappropriate, the SARC Summary Report should include recommendations and justification for suitable alternatives. If such alternatives cannot be identified, then the report should indicate that the existing BRP proxies are the best available at this time.

The contents of the draft SARC Summary Report will be approved by the CIE reviewers by the end of the SARC Summary Report development process. The SARC chair will complete all final editorial and formatting changes prior to approval of the contents of the draft SARC Summary Report by the CIE reviewers. The SARC chair will then submit the approved SARC Summary Report to the NEFSC contact (i.e., SAW Chairman).

Schedule

The milestones and schedule are summarized in the table below. No later than June 22, 2007, the CIE reviewers should submit their Independent CIE Reports to the CIE for review¹. The Independent Reports shall be addressed to "University of Miami Independent System for Peer Review," and sent to Dr. David Sampson,

¹ All reports will undergo an internal CIE review before they are considered final.

via e-mail to David.Sampson@oregonstate.edu and to Mr. Manoj Shivlani via e-mail to mshivlani@rsmas.miami.edu

Milestone	Date
Open workshop at Northeast Fisheries Science Center (NEFSC) (begin writing reports, as soon as open Workshop ends)	June 4-7, 2007
SARC Chair and CIE reviewers work at the NEFSC drafting reports	June 7- 9
Draft of SARC Summary Report, reviewed by all CIE reviewers, due to the SARC Chair **	June 22
CIE reviewers submit Independent CIE Reports to CIE for approval	June 22
SARC Chair sends Final SARC Summary Report, approved by CIE reviewers, to NEFSC contact (i.e., SAW Chairman)	June 29
CIE provides reviewed Independent CIE Reports to NMFS COTR for approval	July 6
COTR notifies CIE of approval of reviewed Independent CIE Reports	July 13 *
COTR provides final Independent CIE Reports to NEFSC contact	July 13

* Assuming no revisions are required of the reports.

** The SARC Summary Report will not be submitted, reviewed, or approved by the CIE.

The SAW Chairman will assist the SARC chair prior to, during, and after the meeting in ensuring that documents are distributed in a timely fashion.

NEFSC staff and the SAW Chairman will make the final SARC Summary Report available to the public. Staff and the SAW Chairman will also be responsible for production and publication of the collective Working Group papers, which will serve as a SAW Assessment Report.

NEFSC Contact person and SAW Chairman:

Dr. James R. Weinberg, NEFSC, Woods Hole, MA. 508-495-2352,
James.Weinberg@noaa.gov

Submission and Acceptance of CIE Reports

The CIE shall provide via e-mail the final Independent CIE Reports in pdf format to Dr. Lisa Desfosse (Lisa.Desfosse@noaa.gov) for review by NOAA Fisheries and approval by the COTR, Dr. Stephen K. Brown, by July 6, 2007. The COTR shall notify the CIE via e-mail regarding acceptance of the reports by July 13, 2007. The COTR will transmit the Independent CIE Reports to the NEFSC contact no later than July 13, 2007.

ANNEX 1:
Terms of Reference for the 45th Northeast Regional Stock Assessment Workshop

(Revised March 7, 2007)

A. Sea Scallops

1. Characterize the commercial catch, effort and CPUE, including descriptions of landings and discards of that species.
2. Estimate fishing mortality, spawning stock biomass, and total stock biomass for the current year and characterize the uncertainty of those estimates. If possible, also include estimates for earlier years.
3. Either update or redefine biological reference points (BRPs; proxies for B_{MSY} and F_{MSY}), as appropriate. Comment on the scientific adequacy of existing and redefined BRPs.
4. Evaluate current stock status with respect to the existing BRPs, as well as with respect to updated or redefined BRPs (from TOR 3).
5. Recommend what modeling approaches and data should be used for conducting single and multi-year stock projections, and for computing TACs or TALs.
6. If possible,
 - a. provide numerical examples of short term projections (2-3 years) of biomass and fishing mortality rate, and characterize their uncertainty, under various TAC/F strategies and
 - b. compare projected stock status to existing rebuilding or recovery schedules, as appropriate.
7. Review, evaluate and report on the status of the SARC/Working Group Research Recommendations offered in recent SARC reviewed assessments.

B. Northern Shrimp

1. Characterize the Gulf of Maine northern shrimp commercial catch, effort, and CPUE, including descriptions of landings and discards of that species.
2. Estimate fishing mortality and exploitable stock biomass in 2006 and characterize the uncertainty of those estimates. Also include estimates for earlier years.
3. Comment on the scientific adequacy of existing biological reference points (BRPs).
4. Evaluate current stock status with respect to the existing BRPs.
5. Perform sensitivity analyses to determine the impact of uncertainty in the data on the assessment results.
6. Analyze food habits data and existing estimates of finfish stock biomass to estimate annual biomass of northern shrimp consumed by cod and other major predators. Compare consumption estimates with removals implied by currently assumed measures of natural mortality for shrimp.
7. Review, evaluate and report on the status of the 2002 SARC/Working Group Research Recommendations.

ANNEX 2: Contents of SARC CIE Independent Reports

1.

For each assessment reviewed, the report should address whether each Term of Reference of the SAW was completed successfully. For each Term of Reference, state why that Term of Reference was or was not completed successfully. To make this determination, CIE reviewers should consider whether the work provides a scientifically credible basis for developing fishery management advice. Scientific criteria to consider include: whether the data were adequate and used properly, the analyses and models were carried out correctly, and the conclusions are correct/reasonable.

If a reviewer feels that his/her comments are adequately expressed in the SARC Summary Report, it will not be necessary to repeat the same comments in the Independent CIE Report. In that case, the Independent CIE Report can be used to provide greater detail on specific Terms of Reference or additional questions raised during the meeting.
2.

If any existing Biological Reference Point (BRPs) proxies are considered inappropriate, include recommendations and justification for alternative proxies. If such alternatives cannot be identified, then indicate that the existing BRPs are the best available at this time.
3.

Any independent analyses conducted by the CIE reviewers as part of their responsibilities under this agreement should be incorporated into their Independent CIE Reports. It would also be helpful if the details of those analyses (e.g, computer programs, spreadsheets etc.) were made available to the respective assessment scientists.
4.

Additional questions that were not in the Terms of Reference but that are directly related to the assessments. This section should only be included if additional questions were raised during the SARC meeting.

ANNEX 3: Contents of SARC Summary Report

1.

The main body of the report shall consist of an introduction prepared by the SARC chair that will include the background, a review of activities and comments on the appropriateness of the process in reaching the goals of the SARC. Following the introduction, for each assessment reviewed, the report should address whether each Term of Reference of the SAW was completed successfully. For each Term of Reference, the SARC Summary Report should state why that Term of Reference was or was not completed successfully.

To make this determination, the SARC chair and CIE reviewers should consider whether the work provides a scientifically credible basis for developing fishery management advice. Scientific criteria to consider include: whether the data were adequate and used properly, the analyses and models were carried out correctly, and the conclusions are correct/reasonable. If the CIE reviewers and SARC chair do not reach an agreement on a Term of Reference, the report should explain why. It is permissible to express majority as well as minority opinions.
2.

If any existing Biological Reference Point (BRP) proxies are considered inappropriate, include recommendations and justification for alternative proxies. If such alternatives cannot be identified, then indicate that the existing BRPs are the best available at this time.
3.

The report shall also include the bibliography of all materials provided during SAW 45, and any papers cited in the SARC Summary Report, along with a copy of the CIE Statement of Work.

The report shall also include as a separate appendix the Terms of Reference used for SAW 45, including any changes to the Terms of Reference or specific topics/issues directly related to the assessments and requiring Panel advice.

Appendix B Terms of reference

B.1 Northern shrimp

1. Characterize the Gulf of Maine northern shrimp commercial catch, effort, and CPUE, including descriptions of landings and discards of that species.
2. Estimate fishing mortality and exploitable stock biomass in 2006 and characterize the uncertainty of those estimates. Also include estimates for earlier years.
3. Comment on the scientific adequacy of existing biological reference points (BRPs).
4. Evaluate current stock status with respect to the existing BRPs.
5. Perform sensitivity analyses to determine the impact of uncertainty in the data on the assessment results.
6. Analyze food habits data and existing estimates of finfish stock biomass to estimate annual biomass of northern shrimp consumed by cod and other major predators. Compare consumption estimates with removals implied by currently assumed measures of natural mortality for shrimp.
7. Review, evaluate and report on the status of the 2002 SARC/Working Group Research Recommendations.

B.2 Atlantic sea scallop

1. Characterize the commercial catch, effort and CPUE, including descriptions of landings and discards of that species.
2. Estimate fishing mortality, spawning stock biomass, and total stock biomass for the current year and characterize the uncertainty of those estimates. If possible, also include estimates for earlier years.
3. Either update or redefine biological reference points (BRPs; proxies for B_{MSY} and F_{MSY}), as appropriate. Comment on the scientific adequacy of existing and redefined BRPs.
4. Evaluate current stock status with respect to the existing BRPs, as well as with respect to updated or redefined BRPs (from TOR 3).

5. Recommend modeling approaches and data to use for conducting single- and multi-year stock projections, and for computing TACs or TALs.
6. If possible,
 - a. provide numerical examples of short term projections (2-3 years) of biomass and fishing mortality rate, and characterize their uncertainty, under various TAC/*F* strategies and
 - b. compare projected stock status to existing rebuilding or recovery schedules, as appropriate.
7. Review, evaluate and report on the status of the SARC/Working Group research recommendations offered in recent SARC reviewed assessments.